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The Post-operative Mortality of Ruptured Abdominal Aortic Aneurysm Repair

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Introduction. *Late peri-operative death after ruptured abdominal aortic aneurysm (RAAA) repair is usually due to multiple-organ failure. The aim of this study was to identify any factors that are associated with mortality in this group of patients.*
Methods. *A retrospective case-note review of a single decade's operative experience of RAAA repair in a single centre. Only those patients with confirmed rupture at laparotomy were included. Sixty-three pre- intra- and post-operative variables were recorded where possible for each patient who survived surgery and the initial 24-hours post-operatively. Multi-variate analysis was performed using stepwise logistic regression. The P-POSSUM, RAAA-POSSUM, RAAA-POSSUM (physiology only), V-POSSUM, and V-POSSUM (physiology only) models were all compared to determine how each performed in these patients.*
Results. *Two hundred and twenty-three cases of confirmed RAAA were identified, of whom 139 survived the operation and initial 24-hours post-operatively. In-hospital mortality in this group of patients was 32.4%. Variables significantly associated with mortality after multi-variate analysis, were low intra-operative systolic blood pressure, the presence of a consultant anaesthetist at the initial operation and the development of cardiac, renal or gastro-intestinal complications. All POSSUM models except the V-POSSUM and P-POSSUM (physiology only) models demonstrated no significant lack of fit in this dataset.*
Discussion. *Factors associated with delayed peri-operative death after RAAA are not the same as those previously found to be associated with overall peri-operative mortality after RAAA repair.*

Introduction

The operative mortality of ruptured abdominal aortic aneurysm (RAAA) repair is estimated to be approximately 48% and has only improved gradually since the procedure was first described.[1] The reasons for this lack of improvement are unknown but identification of factors associated with mortality would clearly facilitate the implementation of strategies to correct or treat these factors and ultimately reduce mortality.

The operative mortality of RAAA repair can be divided into deaths in the immediate peri-operative period (deaths during, or within 24 h of surgery) and post-operative deaths (deaths from 1 to 30 days after surgery). Those deaths in the immediate peri-operative period are usually directly as a result of haemorrhagic shock due to the combination of rupture and the surgical procedure.[2–4] Deaths occurring later in the post-operative period are usually due to major organ system failure either in isolation or, more commonly, multiple-organ failure.[5,6] Whilst the initial event in both those who die during surgery and those who die later in the post-operative period is rupture of an aortic aneurysm the pathophysiological processes leading to death are very different in each group. Deaths due to massive haemorrhage are due to the inability to maintain blood pressure as a result of inadequate circulating volume. Multiple-organ failure is due to the excessive activation of inflammatory pathways as a result of the combined insults of haemorrhagic shock and surgery.[7]

Many studies have attempted to identify factors associated with mortality but usually both early and late deaths are grouped together[8] and since the pathological processes leading to death in these groups are different it follows that different factors may influence mortality in each of these groups. In addition, the group of patients who survive the initial

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peri-operative period pose a significant clinical problem since it is difficult to assess which of these patients have a poor prognosis. The aim of this study was to determine what factors are associated with mortality in patients with RAAA, focussing on those who survive the initial operative procedure of RAAA repair.

Methods

A retrospective case-note review of all patients admitted to the Leicester Royal Infirmary from January 1991 to December 2000 inclusive with a diagnosis of RAAA was performed. Patients were identified from the vascular surgery departmental audit, death certificate records and the admission records of the Accident and Emergency department, operating theatres, intensive care unit and high-dependency unit. The case notes of all patients were retrieved and examined by one of the authors (MJB). Cases were only included in the analysis if rupture was confirmed by the presence of blood outside of the aorta (intra- or retro-peritoneally) at laparotomy for AAA repair. The details of patients that had a clinical or radiological diagnosis of RAAA but not fit enough for surgery were also recorded. Patients with aorto-caval or aorto-enteric fistulas were not included in the analysis. The analysis of factors associated with mortality was restricted to those patients who survived surgery and the initial 24-hour post-operative period.

The data shown in Table 1 was extracted for each case where possible. If any criteria were not specifically recorded in the case-notes these were not assumed to be normal, rather they were treated as missing. POSSUM physiological and operative scores were calculated for each patient only when all the POSSUM components had been recorded. Each of the P-POSSUM,[9] RAAA-POSSUM,[10] RAAA-POSSUM (physiology only),[10] V-POSSUM,[11] and V-POSSUM (physiology only)[11] models were used independently to generate predicted risk of mortality. All calculations and applications of the models were performed following the P-POSSUM methodology, that is standard methods of applying logistic regression models were used.[9]

Mortality was defined as death before discharge from hospital. Post-operative complications were recorded for all patients according to the standards defined by the Committee on Reporting Standards of the Society for Vascular Surgery and the North American Chapter of the International Society for Cardiovascular Surgery.[12] These are divided into systemic and local or vascular complications. The systemic complications are cardiac, cerebral (transient ischaemic attack or cerebro-vascular accident), pulmonary, renal and gastro-intestinal complications. Local/vascular complications are limb ischaemia, intra- or post-operative haemorrhage, wound infection, graft infection, graft thrombosis and wound dehiscence. Patients discharged or transferred to other acute hospitals during the post-operative period were followed-up by either obtaining their notes from those hospitals they were transferred to or by contacting their general practitioners.

Table 1. Criteria recorded for each patient (where present).

Chronic health status	History of: smoking/current smoker, myocardial infarction, cerebro-vascular accident, diabetes, hypertension, hypercholesterolaemia, renal impairment, chronic pulmonary disease
Pre-operative factors	Presenting blood pressure, laboratory investigations (haematology and biochemistry), admission electrocardiograph, transfer from another hospital, cardiac arrest, any radiological investigation performed, time delay from admission to start of operation
Intra-operative factors	Aneurysm size, grade of surgeon, grade of anaesthetist, ASA* grade, prophylactic antibiotic used, graft used (bifurcated, straight), duration of aortic clamping, requirement for/duration of any supra-renal aortic clamping, amount of blood products transfused, peak and trough systolic blood pressure and heart rate, further surgical procedure during operation, division of left renal vein, overall duration of procedure (induction to last entry on anaesthetic chart)
Post-operative factors	Further post-operative surgical procedure required (not tracheostomy for weaning), complications, day first discharged from critical care to acute ward, any readmission to critical care
General data	Patient demographics, outcome, location of death, time to death/discharge

*ASA, American Society of Anaesthesiologists.

Statistical analysis

Univariate analyses examining the association between demographic and clinical characteristics and mortality were carried out. These are reported on a mean difference and odds ratio scales (with 95% confidence intervals (CI)) for continuous and categorically defined variables, respectively.

Multivariate modelling examining the simultaneous and independent effect of the demographic and clinical characteristics was then carried out using logistic regression. A stepwise (forwards–backwards) variable selection procedure was adopted, retaining terms in the model if they were significant at the 5% level.

The statistical package SPSS was used for all analysis.

Results

A total of 576 cases were identified that could potentially be RAAA. Case-notes were unavailable for 220 of these patients, either due to lack of information to enable identification of the patient on the hospital records database or the case-notes had been destroyed (due to a clerical error, 77 cases). Of the remaining 356 cases, 144 did not have a RAAA leaving 222 cases of confirmed RAAA. The majority of those cases found not to have had a RAAA were either urgently operated non-ruptured AAA ($n = 58$) or electively operated AAA ($n = 27$).

Mortality

The median age of all 222 patients with confirmed RAAA was 74 years (range 57–96 years) and 43 were female (19.4%). Thirty-nine patients were not operated upon due to their clinical state and pre-morbid condition on admission, all of these patients died (median age 84 years, range 72–96 years, median time to death 0 days, range 0–5 days). One hundred and eighty-three patients underwent surgery for RAAA and complete details were available for 181, two patients who survived surgery had no post-operative notes available. The in-hospital mortality for these 181 patients was 48.0% (87 deaths). Thirty-day mortality was 46.4% (84 deaths). Twenty-seven patients died intra-operatively (14.9%), 15 patients died within 24 h of surgery (8.3%) and 45 died before hospital discharge after surviving the immediate 24-hour post-operative period (24.9%). In the group of 141 patients who survived surgery and the first 24 h post-operatively complete data was available for 139. Mortality in this group of 139 patients was 32.4% (45 deaths), with multiple-organ failure responsible for 27 of these deaths (60.0% of all deaths). The causes of death for all 87 patients who died is shown in Table 2.

Statistical analysis of factors associated with mortality

This analysis was restricted to those patients who survived surgery and the initial 24-hour post-operative period. The results of the univariate analysis of all factors recorded are shown in Tables 3–5. Categorical variables positively associated with increased odds of death (with 95% CIs that excluded a value of one) were the use of a supra-renal aortic clamp at operation, the senior anaesthetist present at the initial operation being of consultant status, the need to perform any post-operative surgical procedure and the development of any post-operative complication (Table 3). Individual post-operative complications associated with mortality (again, with 95% CIs that excluded a value of one) were cardiac, pulmonary, renal, gastro-intestinal complications and any intra- or post-operative haemorrhage (Table 4). Among the continuous variables analysed the difference in the mean values between those patients who survived and those who died had a 95% CI that excluded a value of zero for the following variables: length of initial operation, amount of blood transfused, amount of

Table 2. Causes of death in those patients operated upon.

Cause of death	Deaths in theatre (%)	Deaths within 24 h of surgery (%)	Post-operative deaths (%)
Haemorrhagic shock	27 (100)	12 (80)	0 (0)
Myocardial infarction	0 (0)	0 (0)	2 (4.5)
Pulmonary embolism	0 (0)	0 (0)	2 (4.5)
Pneumonia	0 (0)	0 (0)	2 (4.5)
Multi-organ failure	0 (0)	3 (20)	27 (61.4)
Renal failure	0 (0)	0 (0)	3 (6.8)
Mesenteric ischaemia	0 (0)	0 (0)	2 (4.5)
Other	0 (0)	0 (0)	7 (15.6)
Total	27 (100)	15 (100)	45 (100)

Table 3. Results of univariate analysis of categorical/binary variables.

Variable	Observations (*n*)	Died *n* (%)	Odds ratio (95% CI)*
Re-admitted to critical care			
No	125	38 (30%)	
Yes	14	7 (50%)	2.29 (0.75–6.98)
Gender			
Female	22	3 (14%)	0.28 (0.08–1.01)
Male	117	42 (36%)	
Positive smoking history			
No	9	3 (33%)	
Yes	59	18 (31%)	0.88 (0.20–3.91)
Current smoker			
No	35	10 (29%)	
Yes	33	11 (33%)	1.25 (0.45–3.50)
Previous myocardial infarction			
No	54	15 (79%)	
Yes	14	6 (43%)	1.95 (0.58–6.570)
Previous cerebro-vascular accident			
No	65	20 (31%)	
Yes	3	1 (33%)	1.13 (0.10–13.14)
Diabetes mellitus			
No	67	21 (31%)	
Yes	1	0 (0%)	0.72 (0.03–18.43)†
Hypertension			
No	39	12 (31%)	
Yes	29	9 (31%)	1.01 (0.36–2.86)
Hypercholesterolaemia			
No	65	20 (31%)	
Yes	3	1 (33%)	1.13 (0.10–13.14)
Documented pre-operative renal impairment			
No	63	18 (29%)	
Yes	5	3 (60%)	3.75 (0.58–24.35)
Pre-operative radiological investigation			
None	94	29 (31%)	
CT	22	10 (46%)	1.87 (0.73–4.81)
USS	19	6 (32%)	10.34 (0.36–2.99)
USS and CT	4	0 (0%)	0.25 (0.01–4.73)†
Grade of senior surgeon present at initial operation			
Consultant	126	45 (36%)	
Senior Registrar/SpR	12	0 (0%)	0.07 (0.00–1.24)†
Grade of senior anaesthetist present at initial operation			
Consultant	63	28 (44%)	
Senior Registrar/SpR	66	14 (21%)	0.34 (0.16–0.73)
Graft type			
Tube	93	60 (32%)	
Bifurcated	43	13 (30%)	0.91 (0.42–1.99)
Antibiotic prophylaxis used			
Cefuroxime and metronidazole	49	15 (31%)	
Co-amoxiclav	49	15 (31%)	1.00 (0.42–2.36)
Cefuroxime	9	4 (44%)	1.81 (0.43–7.72)
Other	3	1 (33%)	1.13 (0.10–13.48)
ASA Grade			
1	1	0 (0%)	
2	4	2 (50%)	3.00 (0.08–115.35)†
3	4	0 (0%)	0.33 (0.00–25.41)†
4	63	21 (33%)	1.52 (0.06–38.85)†
5	33	11 (33%)	1.53 (0.06–40.69)†
Supra-renal clamp			
No	103	25 (24%)	
Yes	36	20 (55%)	3.90 (1.77–8.65)
Further procedure at operation			
No	104	31 (30%)	
Yes	34	14 (41%)	1.65 (0.74–3.68)
LRV divided			
No	133	43 (32%)	
Yes	5	2 (40%)	1.40 (0.23–8.66)
Required post-operative tracheostomy			
No	127	39 (31%)	
Yes	11	6 (55%)	2.71 (0.78–9.41)

Table 4. Results of univariate analysis of specific complications. Numbers given are those positive for each variable over the total number in each category.

Complication	Observations (*n*)	Died *n* (%)	Odds ratio (95% CI)*
Systemic			
Cardiac			
No	84	13 (15%)	
Yes	54	31 (57%)	7.361 (3.306–16.388)
Cerebral (TIA/CVA)			
No	127	38 (30%)	2.811 (0.808–9.772)
Yes	11	6 (55%)	
Pulmonary			
No	71	16 (23%)	2.468 (1.179–5.166)
Yes	67	28 (42%)	
Renal			
No	94	14 (15%)	
Yes	44	30 (68%)	12.245 (5.226–28.688)
GI			
No	113	28 (25%)	
Yes	25	16 (64%)	5.397 (2.147–13.564)
Local/vascular			
Limb ischaemia			
No	131	41 (31%)	
Yes	7	3 (43%)	1.646 (0.352–7.694)
Intra- or post-operative haemorrhage			
No	126	36 (29%)	
Yes	12	8 (67%)	5.00 (1.417–17.643)
Wound infection			
No	132	44 (33%)	
Yes	6	0 (0%)	0.153 (0.008–2.777)†
Graft infection			
No	137	44 (32%)	
Yes	1	0 (0%)	0.700 (0.028–17.538)†
Wound dehiscence			
No	134	43 (32%)	
Yes	4	1 (25%)	0.705 (0.071–6.980)
Other			
No	119	39 (33%)	
Yes	19	5 (26%)	0.733 (0.246–2.180)

*Odds ratio compared to first level of categorical variable.
†0.5 added to all figures (required due to sparse data).

platelets transfused, intra-operative trough systolic blood pressure, diastolic blood pressure on admission, pre-operative serum sodium concentration and pre-operative serum urea concentration (Table 5).

After multi-variate analysis only five of the 17 factors (each specific complication was included separately) that were associated with mortality in the univariate analysis remained significantly associated with mortality ($n = 126$, cut value 0.05) (Table 6). Two of these five factors found to be independently associated with mortality were intra-operative factors (grade of senior anaesthetist present at initial operation and trough systolic blood pressure during initial procedure) and three were post-operative factors (any cardiac, renal or gastro-intestinal complication). Higher risk of mortality was associated with low intra-operative systolic blood pressure and the senior anaesthetist being of consultant status at the initial operation. The post-operative development of either cardiac, renal or gastro-intestinal complications were all independently associated with an increased risk of mortality. This model resulted in an overall prediction rate of 84.9%.

Because of the categorisation of complications into broad sub-groups such as 'cardiac' or 'renal' and the association of these groups of complications with mortality each category of complication was explored separately. Complications occurred in 103 of the 139 patients who survived to 24 h (74.8%) and all patients who subsequently died developed complications. Respiratory complications (ventilation required for respiratory failure, lower respiratory tract infections or adult respiratory distress syndrome) were the most common, occurring in 67 patients (48.6%), cardiac complications occurred in 54 patients (39.1%), renal in 44 patients (31.8%), gastro-intestinal in 25 patients

Table 3 Continued

Variable	Observations (*n*)	Died *n* (%)	Odds ratio (95% CI)*
Further post-operative surgical procedure			
No	116	33 (28%)	
Yes	12	12 (55%)	3.02 (1.19–7.66)
Any complication‡ (preceding death in those who died)			
No	35	35 (100%)	
Yes	103	59 (57%)	53.10 (3.17–889.27)†
Required renal replacement therapy			
No	52	25 (48%)	
Yes	29	20 (69%)	2.40 (0.92–6.25)
Pre-operative inter-hospital transfer			
No	125	40 (32%)	
Yes	14	5 (36%)	1.18 (0.37–3.75)
Pre-operative CPR			
No	137	45 (33%)	
Yes	2	0 (0%)	0.41 (0.02–8.65)†

*Odds ratio compared to first level of categorical variable.
†0.5 added to all figures (required due to sparse data).
‡For associations of specific complications and mortality see Table 4.

Table 5. Results of univariate analysis of continuous variables.

Variable	Observations *n*	Survived Mean (*n*, SD)	Died Mean (*n*, SD)	Mean difference (95% CI)
Age at admission (years)	136	71.0 (91, 7.0)	73.2 (45, 5.6)	−2.19 (−4.56 to 0.18)
AAA size (cm)	43	7.6 (26, 2.0)	7.9 (17, 1.5)	−0.28 (−1.43 to 0.87)
Procedure length (mins)	134	156.4 (90, 55.9)	177.2 (44, 58.9)	−20.79 (−41.50 to −0.09)
Clamp time (mins)	61	66.3 (43, 29.1)	75.4 (18, 24.6)	−9.06 (−24.72 to 6.59)
Supra-renal time (mins)	127	3.3 (87, 15.3)	2.6 (30, 8.4)	−0.26 (−6.07 to 5.56)
Blood transfused (units)	137	8.9 (93, 4.0)	11.2 (44, 4.5)	−2.29 (−3.78 to −0.80)
Platelets transfused (units)	137	3.2 (93, 3.8)	5.5 (44, 4.2)	−2.25 (−3.68 to −0.82)
FFP transfused (units)	137	3.7 (93, 2.7)	4.6 (44, 2.6)	−0.87 (−1.84 to 0.11)
Cryoprecipitate transfused (units)	137	1.0 (93, 2.7)	1.6 (44, 3.3)	−0.66 (−1.71 to 0.40)
Peak intra-operative systolic blood pressure (mmHg)	131	163.0 (88, 25.5)	154.1 (43, 30.0)	8.94 (−0.97 to 18.86)
Trough intra-operative systolic blood pressure (mmHg)	131	87.1 (88, 19.2)	78.1 (43, 13.6)	9.03 (2.56 to 15.50)
Peak intra-operative heart rate (beats/min)	131	102.8 (88, 19.8)	109.2 (43, 20.1)	−6.47 (−13.79 to 0.85)
Trough intra-operative heart rate (beats/min)	131	71.3 (88, 18.4)	77.3 (43, 15.5)	−6.01 (−12.46 to 0.45)
Systolic blood pressure (mmHg) at admission	102	106.1 (65, 48.5)	93.2 (37, 44.6)	12.95 (−6.31 to 32.21)
Diastolic blood pressure (mmHg) at admission	100	62.1 (63, 33.4)	48.0 (37, 35.5)	14.10 (0.04 to 28.15)
Pre-operative mean blood pressure (mmHg)	100	76.9 (63, 37.4)	63.1 (37, 37.0)	13.83 (−1.48 to 29.14)
Pre-operative haemoglobin (g/dl)	90	11.7 (60, 2.5)	11.3 (30, 2.3)	0.43 (−0.65 to 1.52)
Pre-operative white cell count: ($\times 1000/mm^3$)	83	13.1 (56, 4.4)	13.3 (27, 4.1)	−0.19 (−2.20 to 1.83)
Pre-operative platelet count ($/mm^3$)	83	249.2 (56, 138.4)	212.9 (27, 82.5)	36.28 (−21.19 to 93.74)
Pre-operative serum sodium (mmol/l)	78	137.5 (53, 3.6)	135.7 (25, 4.2)	1.85 (0.03 to 3.67)
Pre-operative serum potassium (mmol/l)	78	4.1 (54, 0.7)	4.1 (24, 0.6)	0.03 (−0.30 to 0.35)
Pre-operative serum urea (mmol/l)	80	7.8 (54, 3.5)	9.7 (26, 4.7)	−1.93 (−3.79 to −0.07)
Pre-operative serum creatinine (μmol/l)	79	138.6 (53, 45.7)	154.3 (26, 43.3)	−15.74 (−37.15 to 5.67)
Length of critical care stay* (days)	101	7.5 (90, 7.3)	7.5 (11, 9.1)	0.00 (−4.74 to 4.73)
Length of hospital stay (days)	92	24.5 (92, 19.1)	–	–
Time from admission to surgery (mins)	111	157.6 (66, 194.4)	243.8 (33, 327.8)	−86.23 (−190.53 to 18.08)

SD = standard deviation.

(18.1%), intra- or post-operative haemorrhage in 12 patients (8.6%) and cerebral (cerebro-vascular accident or transient ischaemic attacks) in 11 patients (7.0%). The details of those complications significantly associated with mortality are shown in Table 7.

In order to explore whether multiple systemic complications (cardiac, cerebral, pulmonary, renal or gastro-intestinal) had any effect of mortality patients were categorised into whether they developed no complications, one systemic complication, two systemic complications or greater than two systemic complications (either concurrently or independently during the post-operative period). With increasing numbers of systemic complications mortality increased (Table 8). The odds ratios for death (95% CI), obtained for each of these factors compared to no complications, increased from 7.86 (95% CI 0.90–68.96) for one systemic complication to 133.00 (95% CI 14.99–1180.20) for greater than two systemic complications (Table 8). However, using these four categories in the logistic regression model instead of each of the five systemic complications hardly changed the overall prediction rate, 83.5% in this model compared to 84.9% in the original model.

Trough intra-operative systolic blood pressure was associated with mortality in a linear fashion, patients with lower intra-operative systolic blood pressure had higher mortality. Unfortunately there was no value which could be used as a 'cut-off', below which mortality was 100% since some patients with very low trough intra-operative systolic blood pressure survived. Dividing the 131 patients who had trough intra-operative systolic blood pressure recorded into quartiles based on this variable did demonstrate the relationship between mortality and this variable. Patients with trough intra-operative systolic blood

Table 6. Multivariate analysis: variables found to be significantly independently associated with mortality after ruptured AAA repair.

Variable	β	S.E.(β)	Odds ratio [95% CI]	*P*-value
Constant	0.33	1.30	1.40	0.797
Post-operative cardiac complication	1.92	0.57	6.79 (2.24–20.59)	0.001
Post-operative renal complication	2.25	0.57	9.45 (3.12–28.59)	<0.001
Post-operative gastro-intestinal complication	1.83	0.69	6.21 (1.59–24.24)	0.009
Consultant anaesthetist present at initial operation	−1.14	0.56	0.32 (0.11–0.96)	0.043
Trough intra-operative systolic blood pressure	−0.03	0.02	0.97 (0.94–1.00)	0.027

N = 126. Cut value 0.05. Overall prediction 84.9%.

Table 7. Specific complications in those general groups of complications independently associated with mortality and mortality in each sub-group (Mortality for each general group shown in Table 4).

Class of complication	Specific complication	*N*	Deaths (%)
Cardiac*	Acute ischaemia/myocardial infarction	10	6 (60)
	New arrhythmia	19	8 (42)
	Inotropes required to maintain blood pressure	29	27 (93)
	Acute heart failure	13	3 (23)
	Acute hypertension	4	1 (25)
Renal	Acute renal failure requiring renal replacement therapy	24	15 (63)
	Acute renal failure	18	13 (72)
	Acute renal failure, patient considered not suitable for renal replacement therapy	7	7 (100)
Gastro-intestinal	Ischaemia	6	6 (100)
	Acute gastro-intestinal bleeding	10	6 (60)
	Abdominal compartment syndrome requiring laparostomy	2	1 (50)
	Prolonged post-operative ileus	4	2 (50)
	Intra-abdominal abscess	2	2 (100)
	Jaundice	3	1 (33)

*Twelve patients had two cardiac complications.

pressure less than 73 mmHg (34 patients) had a mortality rate of 50% (17 patients), those with values from 73 to 85 mmHg (40 patients) had a mortality rate of 17% (six patients), those with values from 86 to 95 mmHg (26 patients) had a mortality rate of 27% (seven patients) and those with a value greater than 95 mmHg (31 patients) had a mortality rate of 16 % (five patients).

POSSUM predicted risk of mortality

Complete POSSUM scores were available for 68 patients. Table 9 shows the predicted risk of death and actual mortality rate for each of the POSSUM models used. The P-POSSUM, V-POSSUM, RAAA-POSSUM and RAAA-POSSUM (physiology only) models all demonstrated no lack of fit. The V-POSSUM (physiology only) model demonstrated a significant lack of fit.

Discussion

This study demonstrates the persistent high operative mortality of RAAA repair with the majority of deaths after the initial 24-hour peri-operative period being due to multiple-organ failure. It also clearly demonstrates that the prediction of mortality after RAAA repair is complex. In the group of patients who survive the initial 24-hour peri-operative period the only factors found to be significantly associated with mortality by logistic regression were low intra-operative systolic blood pressure, the grade of senior anaesthetist at the initial operation and the development of either cardiac, renal or gastro-intestinal complications. The factor that had the most significant effect on mortality was the development of renal complications, 85% of patients who developed renal complications died compared to only 32% of those who did not develop any renal complications (Table 4). Mortality increased in a greater than additive fashion with the increasing number of complications occurring in each patient (Table 8), a phenomenon previously observed in patients with multiple-organ failure.[13]

The association of the presence of a consultant anaesthetist at operation and high mortality was unexpected. All of the other factors found to be associated with mortality are clinically plausible whereas the association of a more senior anaesthetist with high mortality is not. It is likely that rather than being the cause of increased mortality the presence of a

Table 8. Relationship between total number of systemic complications (cardiac, cerebral, pulmonary, renal, gastro-intestinal) and mortality.

Number of systemic complications	Observations (*n*)	Died *n* (%)	Odds ratio (95% CI)*
0	39	1 (3)	
1	35	6 (17)	7.86 (0.90–68.96)
2	37	16 (43)	28.95 (3.58–233.95)
>2	27	21 (78)	133.00 (14.99–1180.20)

*Odds ratio compared to first level of categorical variable.

Table 9. Performance of the various POSSUM models examined in the study.

Model	% Range predicted risk	Mean % predicted risk	*N* in range	Predicted mortality	Actual mortality	Chi^2	Overall result for each model
P-POSSUM	>0 to < = 33	16.81	31	5	6	0.14	Chi-squared = 8.065, *P* (4 df) = 0.09
	>33 to < = 50	40.25	16	6	5	0.54	
	>50 to < = 67	56.61	11	6	5	0.56	
	>67 to < = 100	81.85	10	8	5	6.82	
	>0 to < = 100	38.33	68	26	21	8.06	
P-POSSUM (Physiology only)	>0 to < = 5	2.78	34	1	7	39.81	Chi-squared = 79.34 *P* (4 df) = 0.00*
	>5 to < = 15	8.16	26	2	10	31.86	
	>15 to < = 33	20.28	4	1	3	7.41	
	>33 to < = 100	37.61	4	2	1	0.27	
	>0 to < = 100	7.92	68	5	21	79.35	
V-POSSUM	>0 to < = 30	15.43	31	5	6	0.36	Chi-squared = 6.085 *P* (4 df) = 0.19
	>30 to < = 50	38.08	22	8	9	0.07	
	>50 to < = 75	58.27	9	5	3	2.30	
	>75 to < = 100	79.91	6	5	3	3.34	
	>0 to < = 100	34.12	68	23	21	6.08	
V-POSSUM (Physiology only)	>0 to < = 10	5.15	34	2	7	16.59	Chi-squared = 31.04 *P* (4 df) = 0.00*
	>10 to < = 20	13.13	23	3	9	13.63	
	>20 to < = 30	23.07	5	1	2	0.81	
	>30 to < = 100	47.31	6	3	3	0.02	
	>0 to < = 100	12.89	68	9	21	31.05	
RAAA-POSSUM	>0 to < = 40	30.52	24	7	3	3.67	Chi-squared = 9.226 *P* (4 df) = 0.06
	>40 to < = 50	46.28	16	7	5	1.45	
	>50 to < = 75	59.45	21	12	9	2.40	
	>75 to < = 100	77.66	7	5	4	1.70	
	>0 to < = 100	48.02	68	33	21	9.23	
RAAA-POSSUM (Physiology only)	>0 to < = 33	27.52	25	7	4	1.66	Chi-squared = 4.986 *P* (4 df) = 0.29
	>33 to < = 44	39.50	15	6	6	0.00	
	>44 to < = 50	46.25	13	6	5	0.32	
	>50 to < = 100	61.75	15	9	6	3.00	
	>0 to < = 100	41.29	68	28	21	4.99	

*Evidence of lack of fit.

consultant anaesthetist is an indicator of an unstable patient requiring senior anaesthetic input.

The strengths of this study are that it is the first study to examine the factors responsible for increased mortality in the sub-group of patients who survive the initial 24-hour post-operative period. Since the major causes of death change between the intra- and post-operative period (Table 2), the factors responsible for deaths in these two periods are also likely to change. An 'ideal' outcome prediction model for any surgical procedure would be applicable pre-operatively. In the case of RAAA there is usually no time available to wait for laboratory investigations and the only data available are clinical parameters and the patients past medical history. Loss of consciousness after arrival in hospital and a history of chronic heart failure or electrocardiographic evidence of myocardial ischaemia at admission have been found to be associated with mortality in other studies.[8,14] However, these studies do not give details of whether these patients died intra- or post-operatively and, therefore, it is not possible to determine the effect that these factors had on delayed peri-operative mortality as examined in this study. Unfortunately lack of reliably recorded information in the case-notes of patients examined in this study meant that these two variables could not be accurately determined and used in this analysis. Other factors found to be associated with overall (intra- and post-operative) mortality include chronic obstructive lung disease,[15] chronic renal insufficiency,[8,15] ischaemic heart disease,[8,12] elevated anion gap[12] and the development of post-operative renal, cardiac and pulmonary complications.[4]

Three of the five factors found to be associated with mortality in this study were post-operative variables—the development of renal, cardiac or gastro-intestinal complications. Early prediction of these complications would clearly be of clinical use, therapy could be initiated with the aim of preventing the development of these complications. Using a similar logistic regression model to that used in the overall analysis it may have been possible to identify factors that were associated with the development of complications. However, since this would utilise the same variables as used in the overall analysis and the strong association between these complications and mortality it is unlikely that any further useful information would be obtained. In addition, it is not the development of complications that is the important outcome but rather, mortality. Since not all patients who develop a specific complication go on to die it is those factors that are associated with mortality rather than those associated with the development of complications that is more important.

The majority of the POSSUM models examined demonstrated no significant lack of fit when predicted mortality was compared to actual mortality rates. Only the V-POSSUM (physiology only) model demonstrated lack of fit. The P-POSSUM models, despite not being specifically designed for vascular surgery demonstrated no evidence of lack of fit. Of those cases where complete data was available and were consequently subjected to this analysis all deaths were at least 24-hours after surgery. None of the POSSUM models was designed to differentiate between early and late deaths, rather they were designed to model total deaths. It is of interest that generally they exhibit no lack of fit here. It may be that factors that relate to late deaths, as studied here, also relate to all deaths and thus whilst the POSSUM models were developed for all deaths they remain valid in this group of patients. Alternatively, it may be that the original studies in which the models were developed were heavily weighted towards late deaths. The precise reason for the generally good performance of the POSSUM models in this dataset, and for this outcome, cannot be commented upon. However, this study suggests that the POSSUM dataset does contain appropriate risk factors for late deaths. It may be that the POSSUM dataset relates to the relative ability of a patient to survive an insult rather than directly assessing the cause of the insult.

The failure to identify any specific factors associated with mortality that could easily be corrected to improve mortality is disappointing. Using the factors identified in this study to predict outcome in individual patients is also not possible since not all patients who are positive for a particular factor go on to die. To be able to predict outcome in those patients who survive the initial operation and first 24-hours post-operatively would be clinically useful. This would enable better information to be given to relatives regarding prognosis and also allow resources to be directed to those patients at high risk of developing complications.

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